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Systems Engineering for Rapid Prototyping: Friendly Marking Device



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Major Monte Cannon
Major Greg Buckner, Major Greg Butram
Major Michael Jiru, Major Arlene Collazo
Dr Rich Cobb, Dr John Colombi

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**“Can a prototyping development effort
be responsive enough to react to
critical needs while still benefiting
from the rigor of systems
engineering?”**

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Introduction

- Close Air Support (CAS) Background
- Prototyping Approach
- Friendly Marking Device (FMD) Results
- Conclusion/ Observations

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The Problem



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Background

- IAW JP 3-09.3 (2 Sep 05):
 - Close air support (CAS) is air action by fixed- and rotary-wing aircraft against hostile targets that are in close proximity to friendly forces and which require detailed integration of each air mission with the fire and movement of those forces.

- Urban CAS considerations
 - Closer proximity to the enemy
 - Reduced communication time
 - Presence of noncombatants
 - Potential for collateral damage
 - Increased risk of fratricide



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Challenge/ Constraints

- AF Research Lab Rapid Reaction (Core Process 3)
 - Compressed schedule - 5 months from emerging need to prototypes
 - No modifications to the CAS aircraft or pods
 - Technology maturity
 - Resource availability
 - Operational limitations
 - Cost

- Project Objective: *Develop, demonstrate and transition a marking solution that enables a Joint Terminal Attack Controller (JTAC) to establish a common point-of-reference with a Close Air Support (CAS) asset such that the CAS asset can attack an intended target while avoiding fratricide.*

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Background

"In on going Close Air Support (CAS) missions and test using MDS platforms with 3rd Generation Targeting Pods; the Joint Terminal Attack Controller (JTAC) working in the Area of Objective has no covert way of friendly identification."

"The JTAC needs a friendly marking device that can be seen by a targeting pod in either the FLIR or Laser Spot Tracker mode. These emitters will increase the pilot situational awareness and reduce fratricide at the same time."

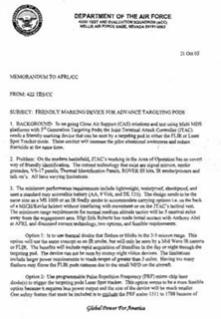
Laser Guided Weapon order on the slow PEP range. This safety measure will prevent the weapon from being used in a friendly fire situation.

4. We believe this is a major problem for AFRL's new process, innovative solutions in laser guided weapons need to be developed to prevent friendly fire situations. We believe that the application of laser and existing technology to solve agent problems mentioned above.

5. Point of Contact: Major Steve W. Roberts, Roberts.William@usaf.mil, (202) 602-7402 (SAC)

[Signature]

Major Steven W. Roberts
U.S. Air Force



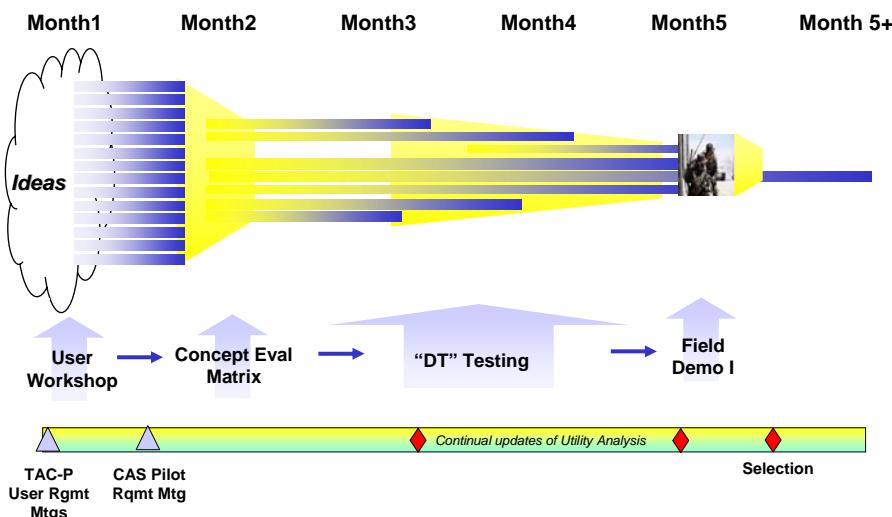
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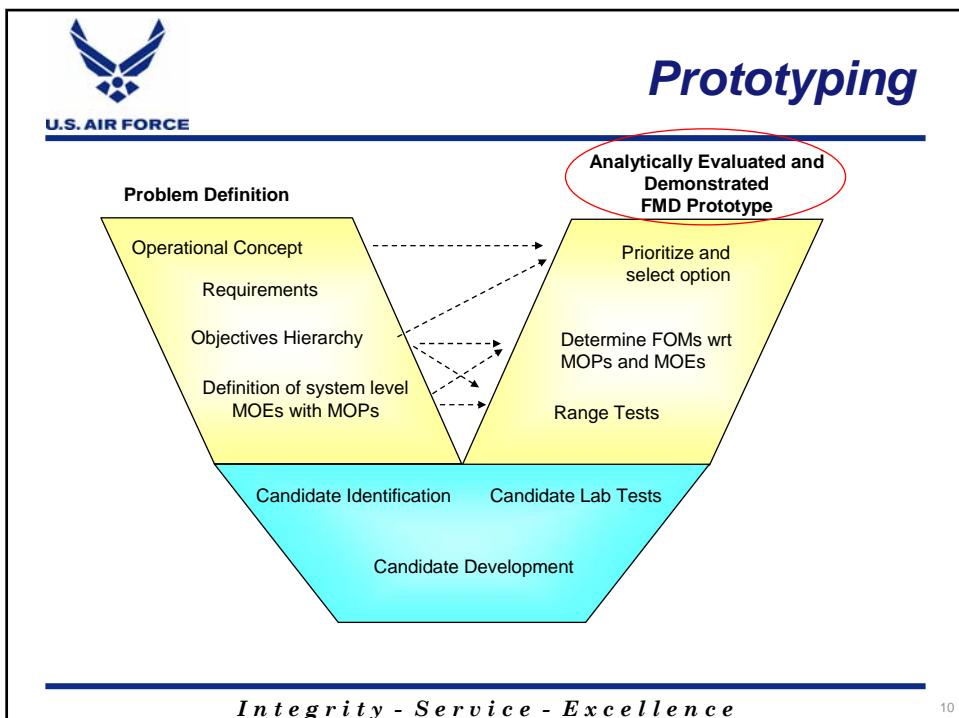
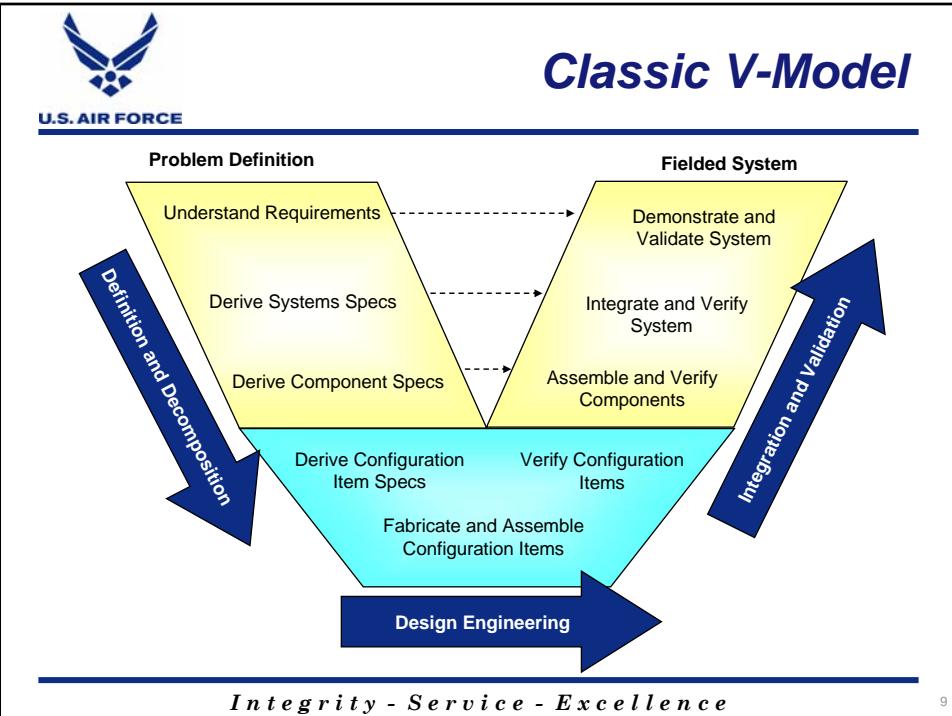
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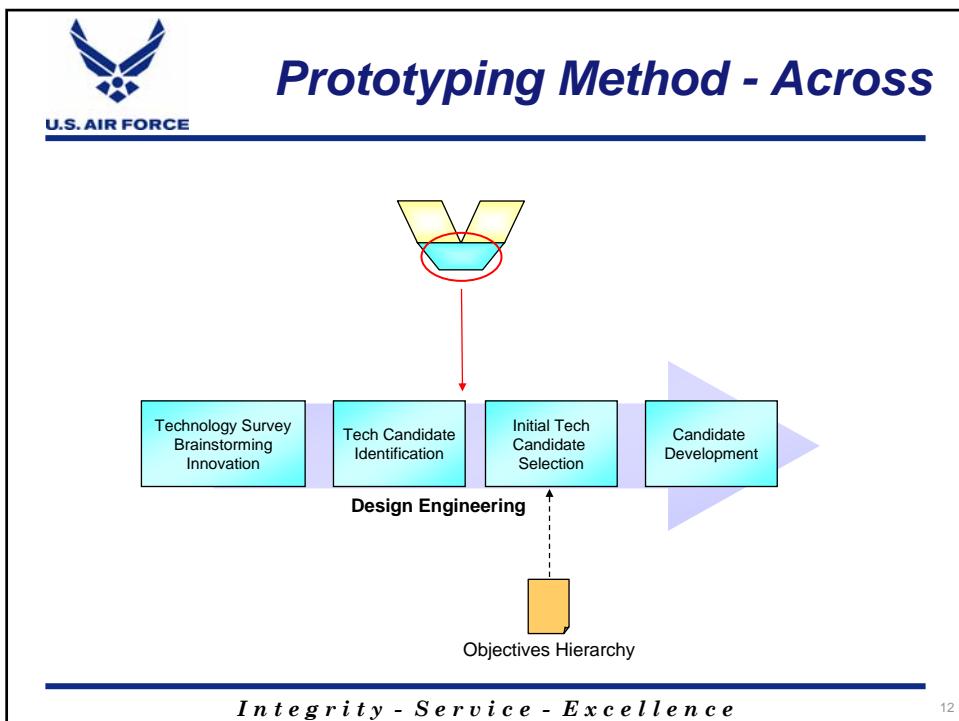
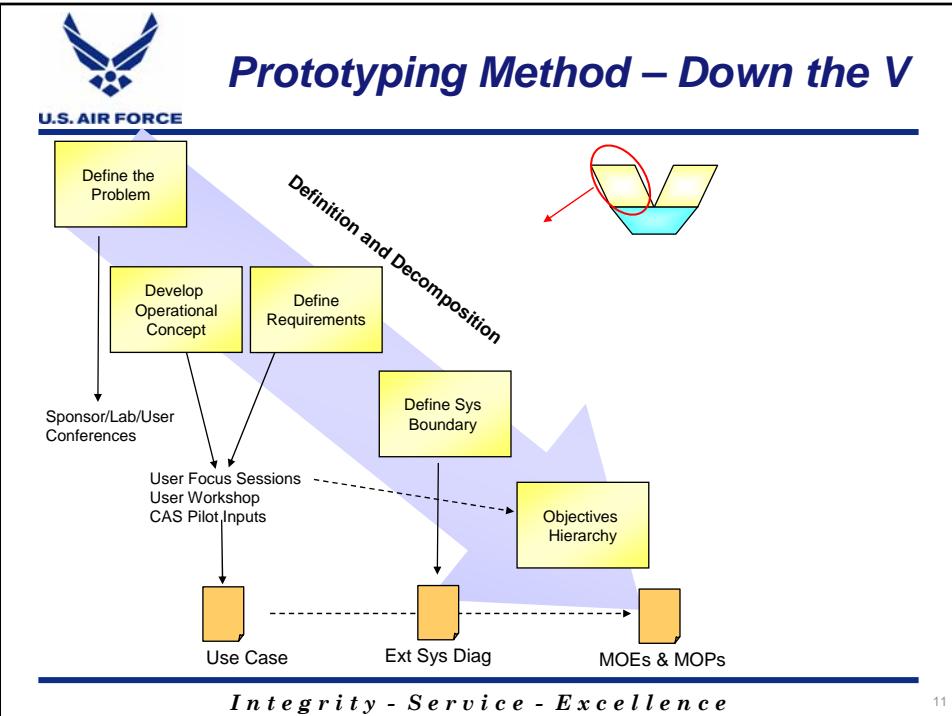
Rapid Reaction Prototyping



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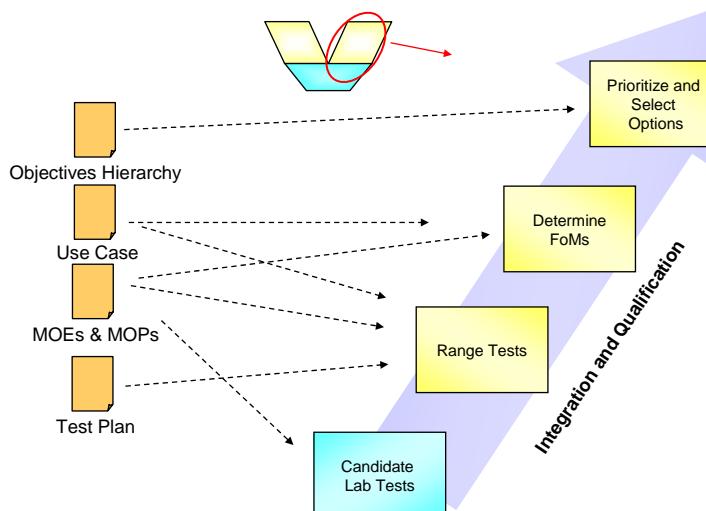






Prototyping Method – Up the V

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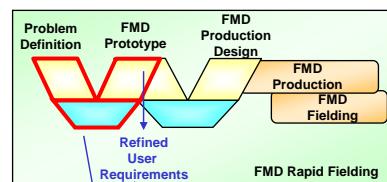
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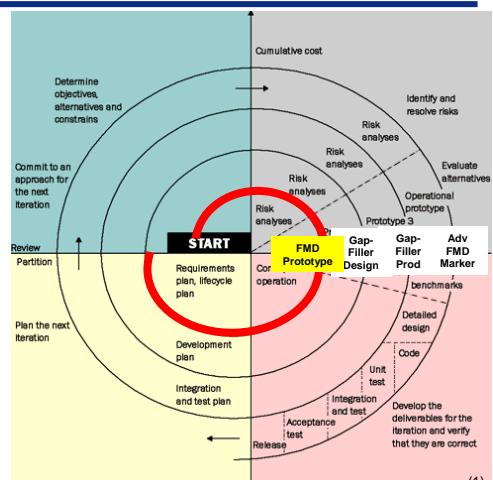
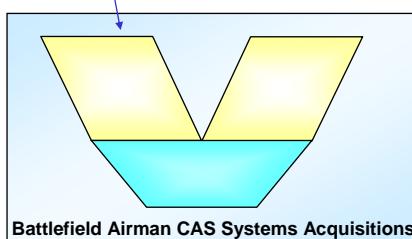


FMD Rapid Prototyping Context

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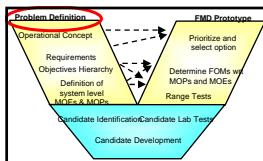
**CAS Friendly ID Long Term Solution
Battlefield Airman ICD/CDD**



(1) (Bkgd Spiral Model Image from en.wikipedia.org/wiki/sprial_model)

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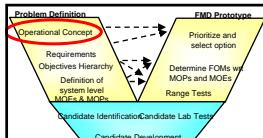


Problem Definition

- Pubs on Close Air Support (JP 3-09.3, Sep 05):
 - Stakeholder Interviews (JTACs and CAS pilots)
 - User Requirement Questions
 - Analysis Criteria
 - Constraints identification
 - Restated problem as:
 - *The Joint Terminal Attack Controller (JTAC) lacks a covert means to quickly and accurately mark the location of friendly forces as a common point-of-reference with a Close Air Support (CAS) asset such that the JTAC can direct a CAS attack with minimum risk of fratricide.*

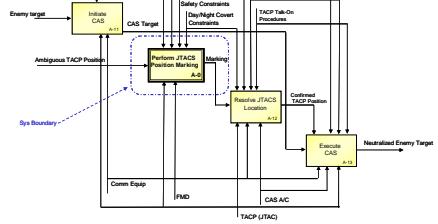
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Develop an Operational Concept

- DoDAF OV-1, High-Level Operational Concept Graphic
 - DoDAF OV-5 External Systems Diagram
 - Use Cases (RUP template)



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Requirements Analysis

The Requirements Analysis process flowchart includes:

- Problem Definition:** Operational Concept, Requirements, Objectives Hierarchy (Definition of system level MOEs & MOPs).
- FMD Prototype:** Prioritize and select option, Determine FOMs w/ MOPs and MOEs, Range Tests.
- Candidate Development:** Candidate Identification/Candidate Lab Test.

A red circle highlights the "Objectives Hierarchy" step.

Use Case refinement

User Requirements with weights

- JTACs
- CAS Pilots

FURPS+ model

- Functional
- Usability
- Reliability
- Performance
- Supportability

“plus” other requirements such as Implementation, Interface, Operations, Packaging, Legal, etc.

User requirements with weights	
Types of Requirements	Requirements
Environmental	Weather Limitations Day/Night Limitations Waterproof
Physical	Shockproof Power Source Weight Size Dimensions
Operational (signal)	Signal Duration Signal Covertness Signal Field of View Signal Range Accuracy Resolution Signal Spectra System Compromise Unique Signal Signal Transmission Delays
Operational (system)	Ease of use / training required Modification required
Acquisition (Long term)	Unintended signal display Long-term unit cost Product Feasibility
Acquisition (Short term)	Estimated cost Prototype availability System Maturity: estimated TRL Factors influencing prototype development

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Objectives Hierarchy

The Objectives Hierarchy table shows the following hierarchy and weights:

- Environmental:** Weight 0.1, Score 0.9, Element Value: Waterpx (0), Weight (0), Cap/Net (0).
- Physical:** Weight 0.2, Score 0.8, Element Value: Shockpx (0), Weight (0), Power S (0), Weight (0), Size (0).
- Ops - Signal:** Weight 0.3, Score 0.9, Element Value: Signal C (0), Weight (0), Signal Co (0), Signal R (0), Signal Range (0), Unintended P (0), Signal Spectrum (0), Signal Compromise (0), Unique Signal (0), Signal Trans Delays (0).
- Mark Position:** Weight 0.6, Score 0.8, Element Value: Ease of Use (0), Weight (0), Modification Req (0), Unique Signal Display (0).

A red circle highlights the "Objectives Hierarchy" step in the flowchart.

A red arrow labeled "User defined" points from the "Weights" column of the table to the "Range Utility Curve" graph.

Range Utility Curve

The graph plots Value (Y-axis, 0 to 1.1) against Range (NM) (X-axis, 0 to 11). A blue curve represents Series 1, starting at (0,0) and rising to approximately (11, 0.95). A horizontal grey line marks the "5 NM Threshold".

Risk-Neutral Utility curves

Based upon user requirements & expressed desires

Each candidate is scored

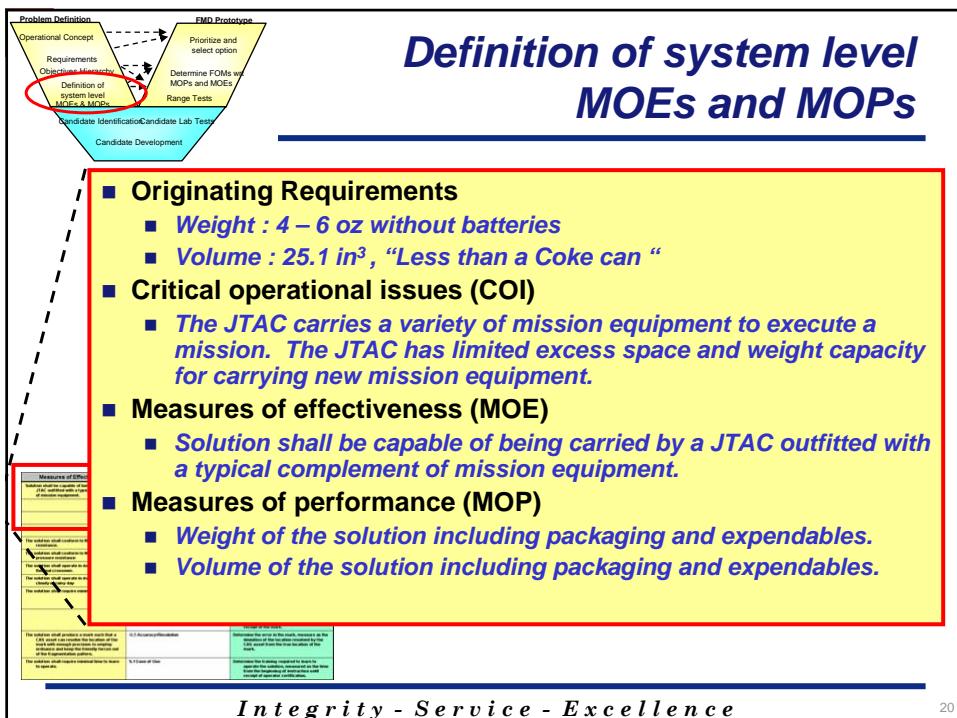
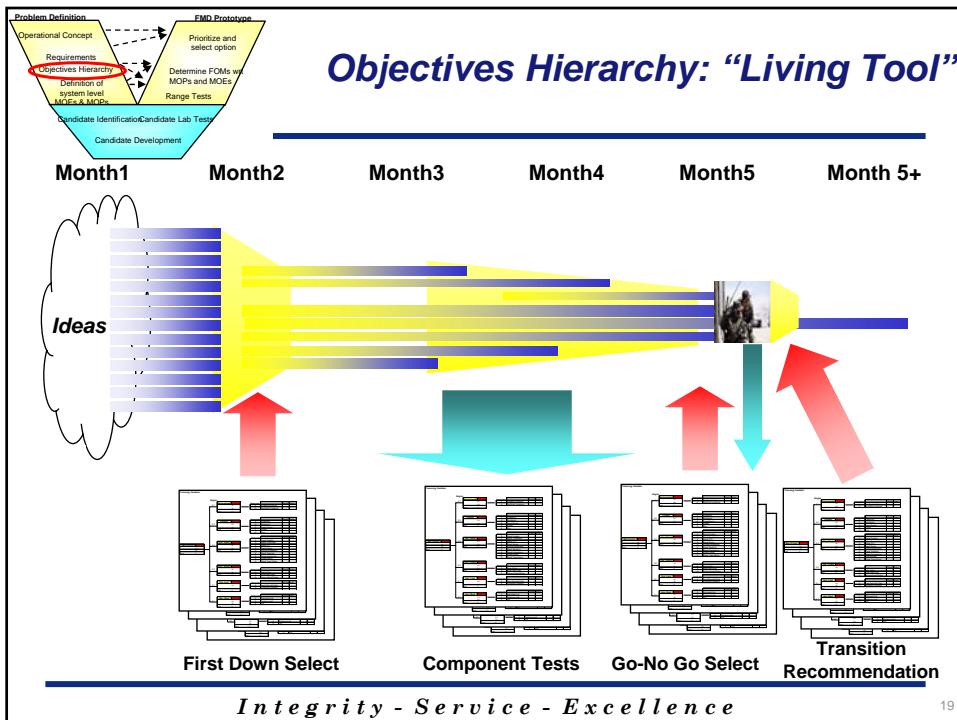
Updated as candidates matured (ie: test data)

Long/short term acquisition elements based upon engineering judgement

	Weight	Score
Ease of Use		
Modification Req		
Unique Signal Display		
Long Term Unit Cost		
Production Feasibility		
Estimated Cost		
Prototype Avail		
TRL		

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Identify/ Develop Technology Candidates

■ AF Research Lab (AFRL) already had many concept ideas

■ Team utilized several “brain storming” sessions to refine possible technologies

1064 Laser	1064 Laser	1064 Laser	1064 Laser
3.5 micron LED	3.5 micron LED	3.5 micron LED	3.5 micron LED
3.5 micron Heater	3.5 micron Heater	3.5 micron Heater	3.5 micron Heater
371 Laser	371 Laser	371 Laser	371 Laser
371 Thermal Emitter Array			
371 Open Bulb Flashlight			
Laser Material	Laser Material	Laser Material	Laser Material
Laser Marker	Laser Marker	Laser Marker	Laser Marker
Laser Warning Receiver	Laser Warning Receiver	Laser Warning Receiver	Laser Warning Receiver
Lasers	Lasers	Lasers	Lasers
Special Material Locator	Special Material Locator	Special Material Locator	Special Material Locator
SOON I	SOON I	SOON I	SOON I
SOON II	SOON II	SOON II	SOON II
Thermal Signaling Device	Thermal Signaling Device	Thermal Signaling Device	Thermal Signaling Device
Thermal Heater	Thermal Heater	Thermal Heater	Thermal Heater
Thermal Heater Array	Thermal Heater Array	Thermal Heater Array	Thermal Heater Array
Thermal Space Heater	Thermal Space Heater	Thermal Space Heater	Thermal Space Heater

Thermal Emitter Box Array

Thermal Emitters

Special Materials

LEDs

Laser

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Candidate Lab Tests

■ Component level testing conducted during prototype development

- Integration of all the pieces
- Evaluate Signal Quality / Duration
- Determine a Signal Detection Range
- Identify Risk Areas / Limitations

082:19:59:06.575

3-5 micron

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Range Test Go/No-Go Selection

```

    graph TD
        PD[Problem Definition] --> OC[Operational Concept]
        OC --> RH[Requirements & Objectives Hierarchy]
        RH --> FD[FMD Prototype]
        FD --> P[Prioritize and select option]
        P --> D[Define FOMs w/ MOPs and MDEs]
        D --> RT[Range Test]
        RT --> GNGS[Go/No-Go Selection]
        GNGS --> CD[Candidate Development]
        CD --> CID[Candidate Identification/Candidate Lab Test]
        CID --> FD
    
```

Range Test Go/No-Go Selection

- Prototype Testing & Production Estimates
 - Confirming pre test mathematical analysis
 - Component test results – Detection Range
- Objective Hierarchy updates
- Final Go / No-Go Selection

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Range Test Plan

```

    graph TD
        PD[Problem Definition] --> OC[Operational Concept]
        OC --> RH[Requirements & Objectives Hierarchy]
        RH --> FD[FMD Prototype]
        FD --> P[Prioritize and select option]
        P --> D[Define FOMs w/ MOPs and MDEs]
        D --> RT[Range Test]
        RT --> GNGS[Go/No-Go Selection]
        GNGS --> CD[Candidate Development]
        CD --> CID[Candidate Identification/Candidate Lab Test]
        CID --> FD
    
```

Range Test Plan

- Development of Prototype Test Plan
 - Prioritized Test Point Matrix
 - Highest weighted areas in Objective H
- Objectives
 - Determine Detection Range
 - Operator Usability Assessment
- Flight Profiles
 - Profile 1 - Open, flat terrain
 - Profile 2 - Urban complex
 - Profile 3- Elevated terrain, stand-off pos
- Evaluation
 - Sniper & LITENING pods
 - F-15E, F-16, A-10 aircraft mix

Nevada Test & Training Range

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Example Test Setup

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Range Test (A-10 at 11nm)

A-10
Litening TGP

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Summary Test Results

■ TEB & TSD V longest detection range

■ Aircrew assessment

- Pod Narrow Field of View - best
- Modulated signal easier to pick out
- Current configurations good for convoy support now

■ JTAC assessment

- Detection ranges exceed expectation
- Instant turn on and off
- Hands free operation preferable
- NVG Covert still nice to have
- Multiple modulation rates

Device	F-15E Sniper	Predator	A-10 - LITENING
TEB (20)	12 nm	9.5 nm	18 nm
TEB (12)	6 nm	10 nm	not tested
TSD II	4 nm	11 nm	11 nm
TSD III	3 nm	12 nm	11 nm
TSD IV	11 nm	11.5 nm	10 nm
TSD V	not tested	10 nm	18 nm
LED	no detection	no detection	not tested
Israeli	not tested	no detection	not tested
LWR	not tested	not tested	dead battery

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Prioritize and Select Options

Thermal Emitter Box

- Detection distance greater than 10 nm
- Potential to miniaturize for helmet mounting (hands-free)

Thermal Emitter Box Array

Thermal Emitter Beacon (Box array)	0.86
Special Material Locator Marker	0.82
Thermal Signalling Device II	0.65
Thermal Signalling Device III	0.65
Thermal Signalling Device IV	0.60
Thermal Signalling Device V	0.60
LED (3-5 mic)	0.47

Special Material Locator Marker

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Conclusion

- Application of systems engineering rigor compatible under “rapid response”
- Technology available to identify friendly forces during urban CAS
- Several SE Observations
 - SE can be tailored to rapid prototyping while maintaining rigor
 - Understanding key constraints and the larger context provided a decision-making framework for the project
 - Proven techniques from software engineering were applicable in a rapid hardware prototyping effort
 - Selection of SE tools facilitated the decision-making process
 - The systems engineering team helped link users and technology providers together to produce an effective collaboration
 - Parallel COTS Integration reduced overall risk of the project
 - Priority given to the project varied across participants
 - Rapid prototyping requires a creative transition plan

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? QUESTIONS ?



LtCol John Colombi
john.colombi@afit.edu

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